INNOVATIVE DEVICES FOR AMPLIFICATION OF IONIZATION CHARGE IN LIQUID ARGON TIME PROJECTION CHAMBER DETECTORS

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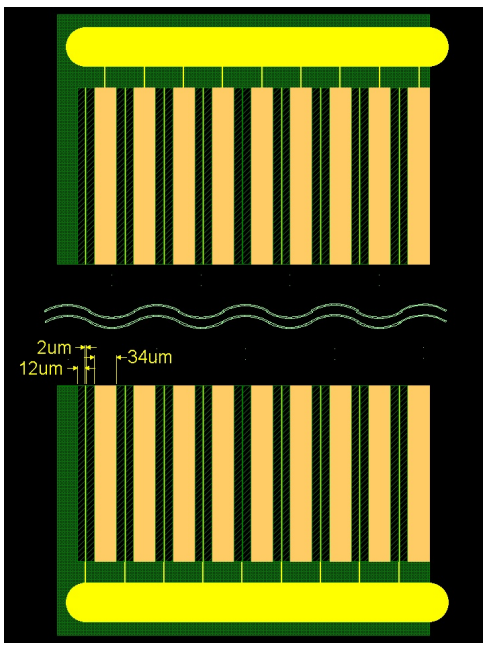
Introduction

The groundbreaking idea we are proposing is the development of innovative devices to multiply and collect electron charge generated by ionizing particles passing through liquid Argon (LAr) medium.
The primary motivation is to make single-phase Liquid Argon Time Projection Chamber detectors (LAr-TPCs) sensitive to events with energy deposition of the order of 10 keV or less, 100 times smaller than present state of the art. This will allow single-phase LAr-TPCs to have an energy threshold comparable with the one of double-phase LAr-TPCs without their technical hurdles (difficulty to use quenching dopants in gas phase, limited multiplication gain, need of fine alignment of electron extraction system with liquid/gas interface).

The Idea/Concept

Tracking in LAr-TPCs is based on the collection of ionization electrons, produced by the interaction of charged particles with the target medium and drifted by a uniform electric field over paths up to a few meters long.
The ~10 signal to noise ratio presently achievable with the adoption of low noise electronics (~1000 electrons), although adequate for detecting minimum ionizing particles (~2 MeV/cm), is largely insufficient to detect events in the keV energy region.
The novel idea [1] is to seek the multiplication of ionization electrons directly in LAr at the end of their drift path, with an anodic plane capable of generating an electric field locally large enough (> hundreds kV/cm) to trigger the proportional multiplication of charge carriers.
The first prototype layout is a scaled-down version of the Micro Strip Gas Counters successfully adopted in gas TPCs: will consist of an array of 2 µm wide strips with 60 µm pitch kept at ground potential, playing the role of the wires in a traditional LAr-TPC. They will be interleaved by larger 34 µm wide strips, negatively biased in order to ensure the quick removal of ions produced in the avalanche near the anodic plane, besides maximizing the collection efficiency. This architecture can be realized on a FR-4 support with the UV lithography technique, the strips being made of a gold film deposited over a 3-5 nm Cr substrate. To average out mechanical imperfections, the narrower electrodes will be read together in groups: f.i., a multiplicity of 50 will reproduce the 3 mm wire pitch of present LAr-TPCs.



Indications of the feasibility of the project come from the positive results of pioneering attempts to multiply charge in LAr in proximity of micrometric wires [2]: the showstoppers encountered at that time, mainly fragility of the wires and limited amplification, could be overcome in present days by modern expertise in micro and nano-techniques.

Potential Impact

The impact on Particle Physics of low energy rare events is potentially dramatic, mainly in searches for Dark Matter interactions and coherent neutrino scattering characterized by O(100 keV) experimental signature and a O(10^{-40} cm^2) cross section. Beyond fundamental Physics researches, achievements of the project will have immediate and interdisciplinary applications in Gamma-ray telescopes for measuring polarization of Gamma-rays and in high resolution Compton spectrometers for medical imaging or identification of explosive devices.

[1] A. Fava, “LArCA - Development and production of innovative devices for amplification of ionization charge in liquid Argon Time Projection Chambers”, proposal RBSI14EB46 to the Italian “SIR Program” 2014.

[2] S.E.Derenzo et al., “Recent developments in high-resolution noble-liquid counters”, eConf C700622 (1970) 45-74.